NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

CONFIDENTIAL BULLETIN



# PRELIMINARY RESULTS OF FLIGHT TESTS OF A CONVENTIONAL THREE-BLADE PROPELLER AT HIGH SPEEDS

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April 1942

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## INTRODUCTION

As part of the program of flight tests of airplane propellers to determine compressibility effects at high speeds, preliminary flights have been made with a conventional three-blade propeller (Hamilton Standard 3155-6) on a Bell YP-39 airplane.

This preliminary report presents the high-speed data obtained thus far with a brief analysis of the results.

## DESCRIPTION OF PROPELLER AND TEST EQUIPMENT

General specifications of the propeller and power plant are as follows:

| | |
|---|---|
| Propeller | Hamilton Standard three-blade |
| Blade | Hamilton Standard 3155-6 |
| Diameter | 10 feet, 3/4 inch |
| Engine | Allison V-1710-35 |
| Propeller gear ratio | 1.8 to 1.0 |

Tests were made without cuffs and with a spinner covering approximately the inner 18 percent of the propeller blades. Figure 1 shows the propeller-spinner combination and the right survey rake on the Bell YP-39 airplane. In figure 2 the developed plan form and blade sections of the Hamilton Standard 3155-6 blade are given.

All instruments were of the recording type. Indicated airspeed was measured by an NACA boom airspeed recorder

mounted under the right wing near the tip. Short pressure lines to a pitot head mounted ahead of the wing provided essentially lag-free operation.

Pressure altitude was measured by an altimeter connected to the static pressure side of the service airspeed head.

Free air temperature was measured by a galvanometer connected to a resistance bulb mounted under the right wing.

A counter was used to measure engine and propeller speed.

Propeller torque was measured by pressure recorders connected to a specially constructed oil pressure type torque meter built into the propeller gear box.

Thrust was measured directly by total head surveys made behind the propeller. For these surveys two rakes extending, on either side of the fuselage, across the propeller disk were used. The pressures were recorded by a multiple manometer which measured the difference between free-stream and slipstream total head pressure. A schematic drawing of the survey rakes and the instrument hookup is given in figure 3.

It was also attempted to measure thrust by pressure recorders connected to thrust meter in the propeller gear box. Corrections for the axial forces due to pressures developed on the spinner were determined in the wind tunnel. However, because of the necessary extrapolation of the corrections to flight conditions, the values of thrust thus obtained were considered unreliable.

## TEST PROCEDURE

All runs reported herein were made at full throttle at altitudes ranging from 16,000 to 23,000 feet. With full throttle and with the propeller set to govern at 3000 rpm the airplane speed was increased to the desired test speed. When this speed was reached the propeller pitch was locked and a record of a few seconds' duration was taken. Runs were made at true speeds ranging from 273 to 468 miles per hour.

## RESULTS AND DISCUSSION

Representative propeller thrust loading curves as determined by an average of the right and left survey rakes are given in figure 4. The areas under these curves are proportional to the thrust. These surveys may indicate a thrust which is slightly high due to the fact that an average total head pressure does not indicate exactly the average momentum when the pressures are fluctuating. However, this will not appreciably affect the qualitative value of the results. In addition, there has been no attempt made to apply a static pressure correction to the propeller wake.

Of primary interest in figure 4 is the marked increase in drag of the blade shanks as the speed is increased.

Curves of efficiency plotted against true airspeed are given in figure 5. Because the propeller rotational speed was maintained essentially constant, the true airspeed is proportional to $V/nD$. In one curve the efficiency is based on the complete survey and includes the shank drag. In the other curve, the efficiency is based on only the working part of the blade, that is, on the part of the propeller that is producing positive thrust. Torque as measured by the torque meter was used to calculate the efficiency in both cases. Accordingly, because the torque absorbed by the shanks was not subtracted from the total torque, the efficiency of the working part of the blade will be somewhat low. Again, however, the qualitative value of the results remains unchanged.

It is seen that the net propeller efficiency tends to drop at speeds above 350 miles per hour. The surveys indicate that this loss is chargeable to a marked increase in drag of the inner portions of the blade.

The working part of the blade experiences little change in efficiency up to the maximum speed tested (468 mph). This corresponds to a tip Mach number of approximately 1.06.

These preliminary data indicate that it is possible to maintain relatively good propeller efficiencies with conventional blade shapes and sections to at least 450 miles per hour provided that excessive drag for the inner portions of the blade can be avoided. If the propeller

shanks were operating in a low velocity region, as they would in front of a blunt body such as a conventional air-cooled engine installation, this loss probably would not occur.

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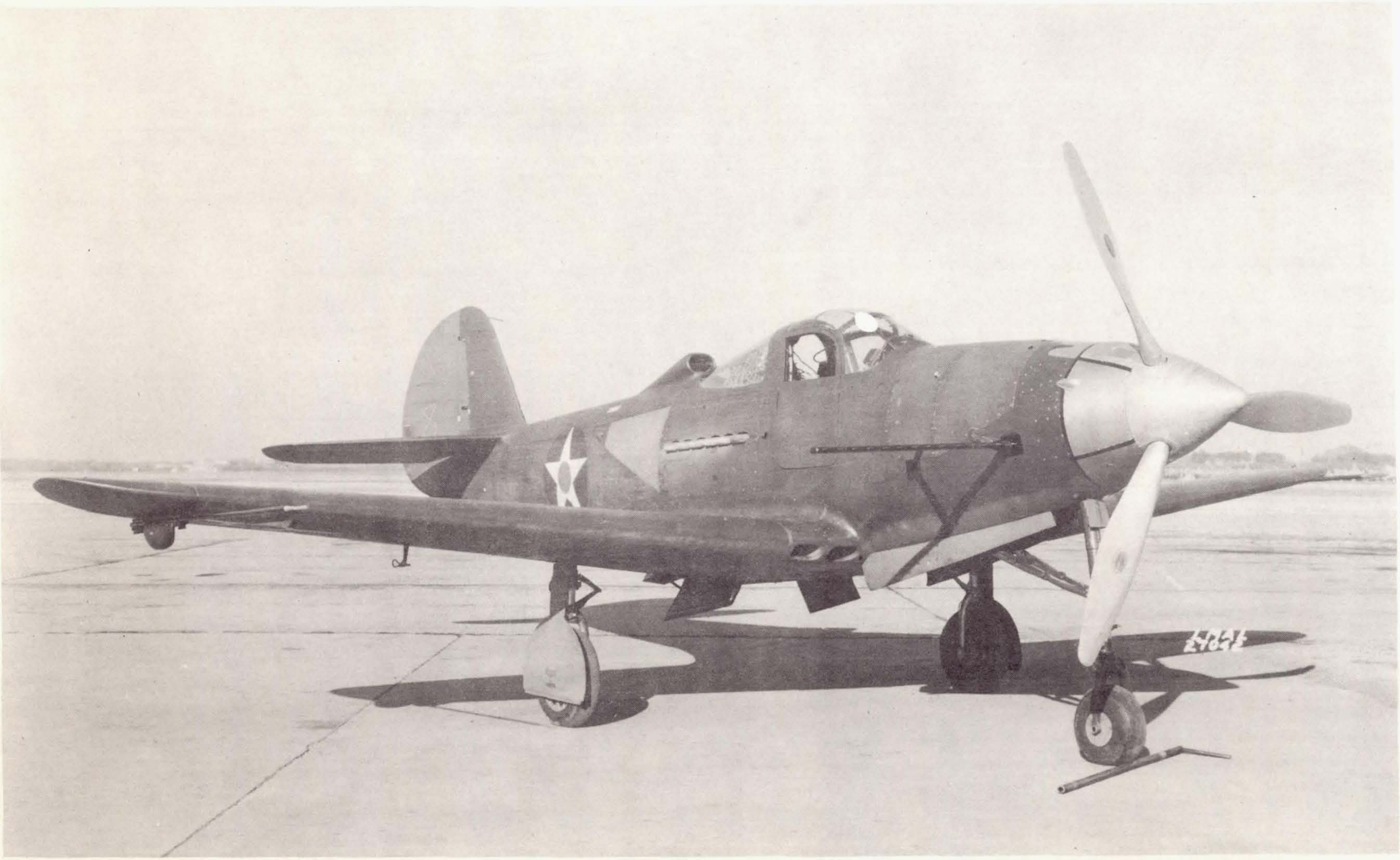



Figure 1.- Bell YP-39 airplane showing survey rake and propeller-spinner combination.

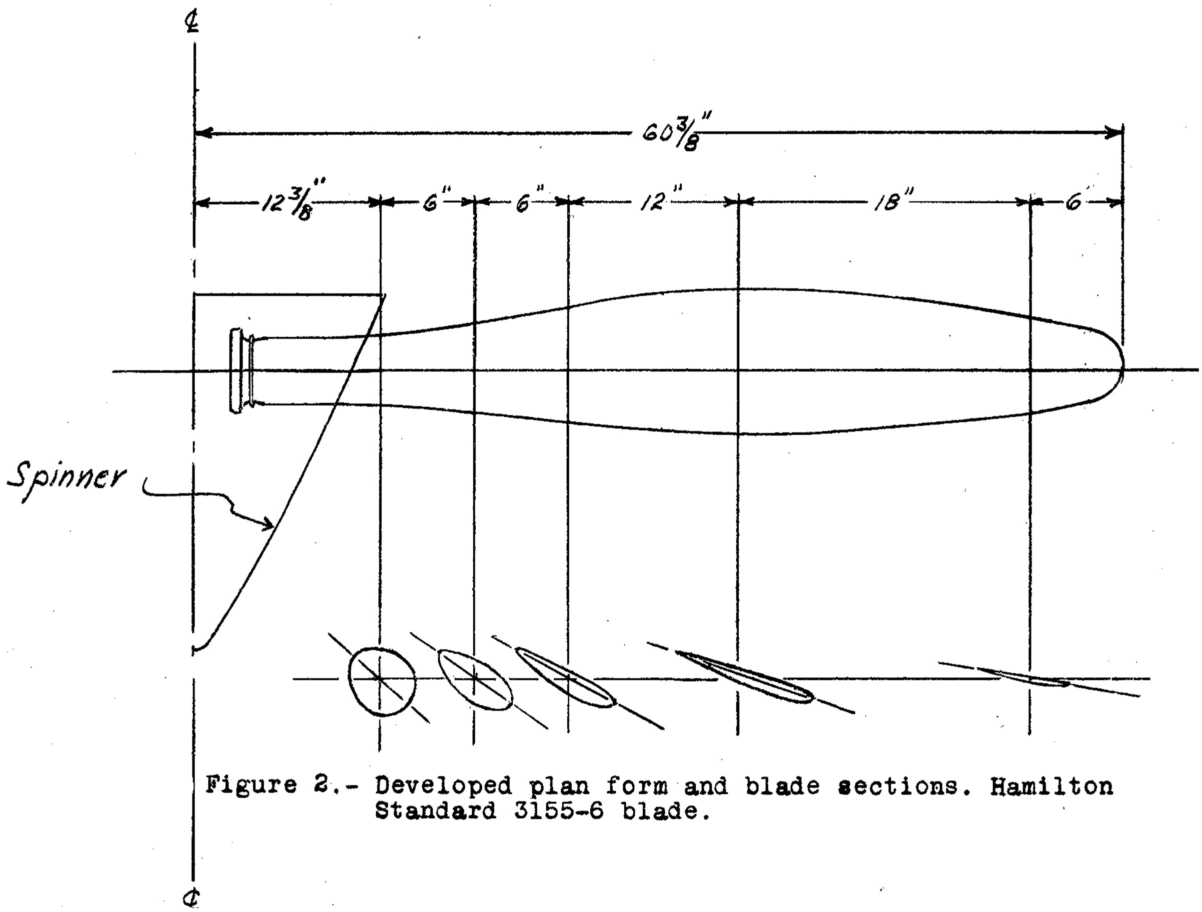


Figure 2.- Developed plan form and blade sections. Hamilton Standard 3155-6 blade.

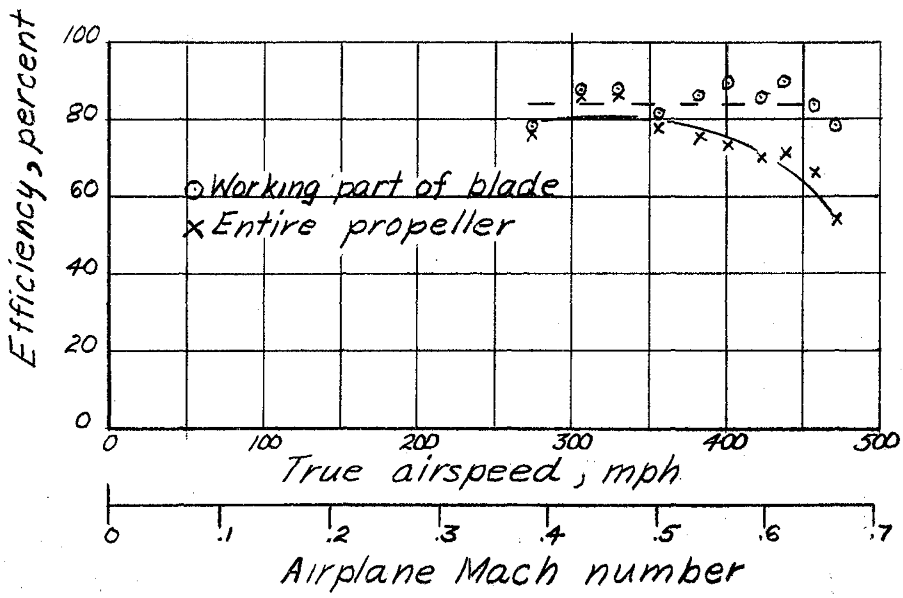


Figure 5.- Propeller efficiencies at high speeds. Hamilton Standard three-blade propeller (Blade 3155-6).

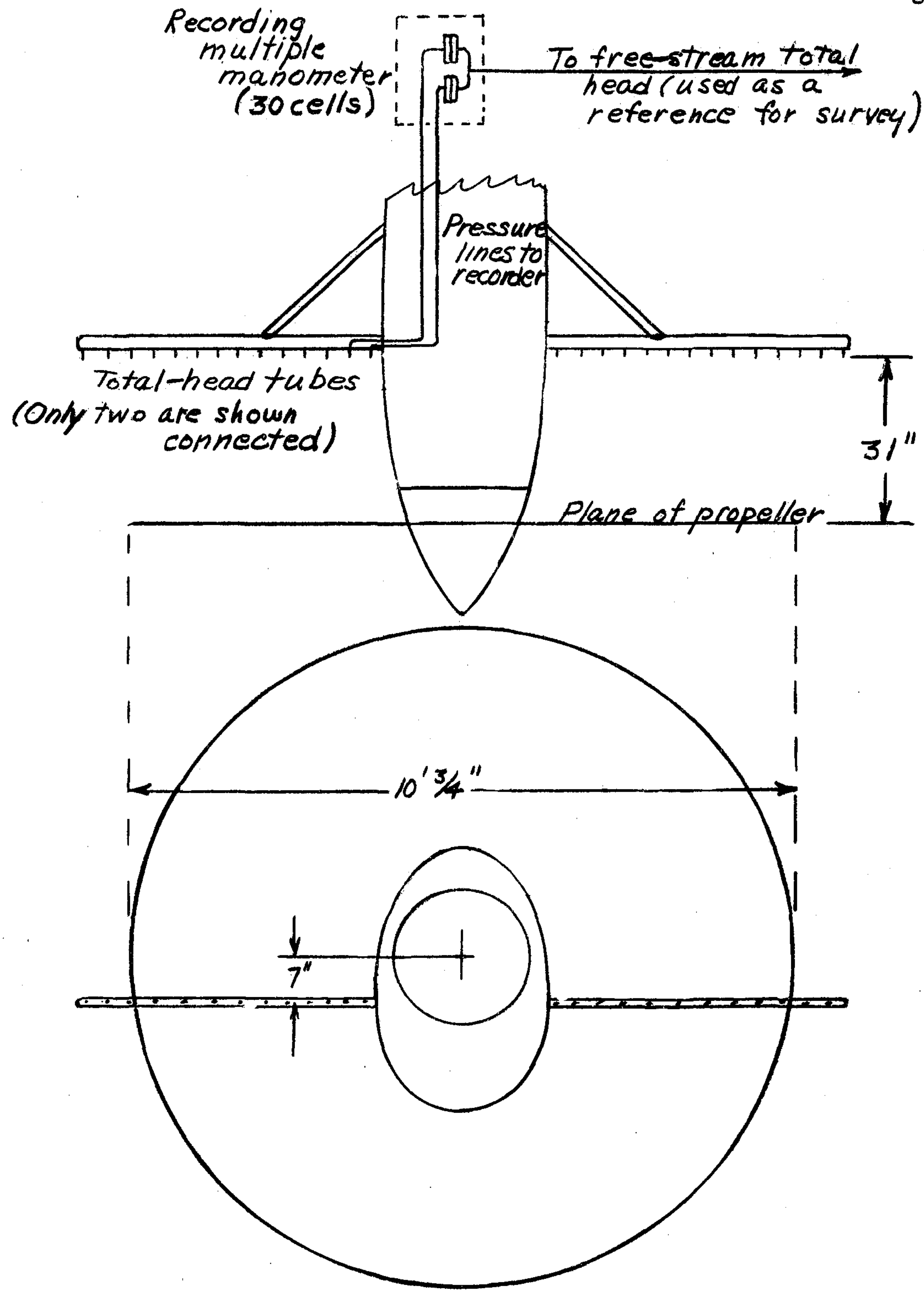


Figure 3. - Propeller survey rakes and manometer hook-up. High-speed propeller tests on Bell YP-39 airplane.

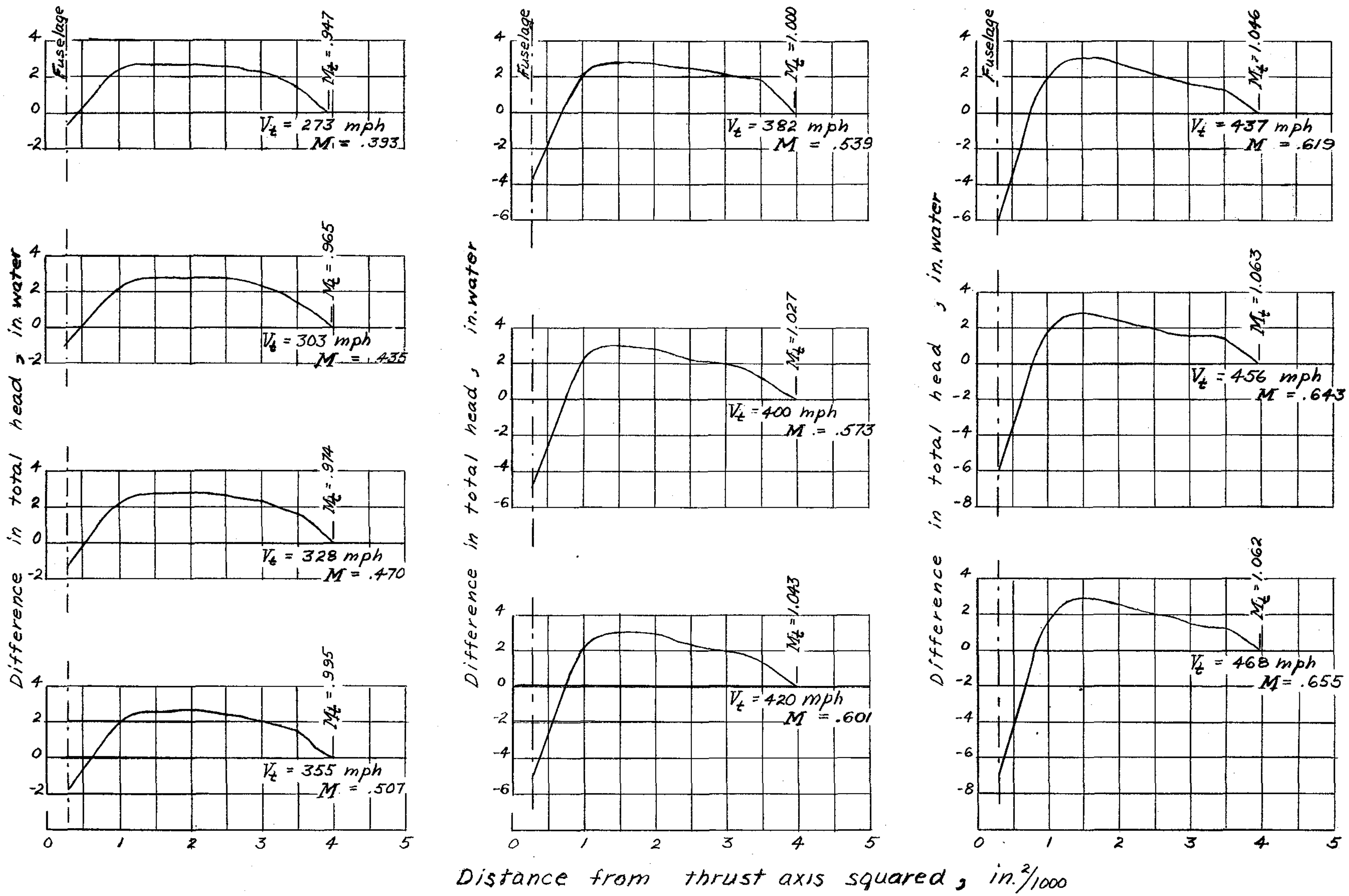


Figure 4.- Propeller thrust loading curves for Hamilton Standard three-blade propeller (blade 3155-6) at various speeds. Values of airplane true speed, $V_t$; airplane Mach number, M; and propeller tip Mach number, $M_t$, are shown.

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SUPPLEMENT TO CONFIDENTIAL BULLETIN

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TABLE I

Density Altitude and Engine Horsepower Corresponding to the Various Test Airspeeds for Curves in Figure 4

| $V_t$ | Density altitude | Brake horsepower |
|---|---|---|
| 273 | 21,800 | 748 |
| 303 | 20,300 | 785 |
| 328 | 19,680 | 838 |
| 355 | 19,450 | 852 |
| 382 | 18,620 | 910 |
| 400 | 18,000 | 907 |
| 420 | 17,480 | 987 |
| 437 | 16,620 | 1017 |
| 456 | 16,670 | 1045 |
| 468 | 15,780 | 1094 |